Regulation Driven ES – Business cases

Lessons learned from implementing battery storage at TSO level

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Energy Storage Global Conference
Explaining I Exchanging I Enabling
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Content

Terna is…

- ...the **largest independent transmission system operator** (TSO) in Europe and the sixth in the world
- ...the **owner** of the Italian High Voltage National Transmission Grid
- ...**responsible for the transmission and dispatching of electricity** throughout the Country
- ...in charge of the development and maintenance of the Grid, employing a workforce of ~3,500
- ...listed on the Italian Stock Exchange since 2004, with a market cap of about € 6.8 Billion.

Numbers ...

Grid

~ 63,500 Km of three-phase conductors in Italy

22 Interconnections lines with foreign countries

468 Substations

Assets

8 Transmission Operating Areas

8 Distribution Centers

3 Remote-Control Centers

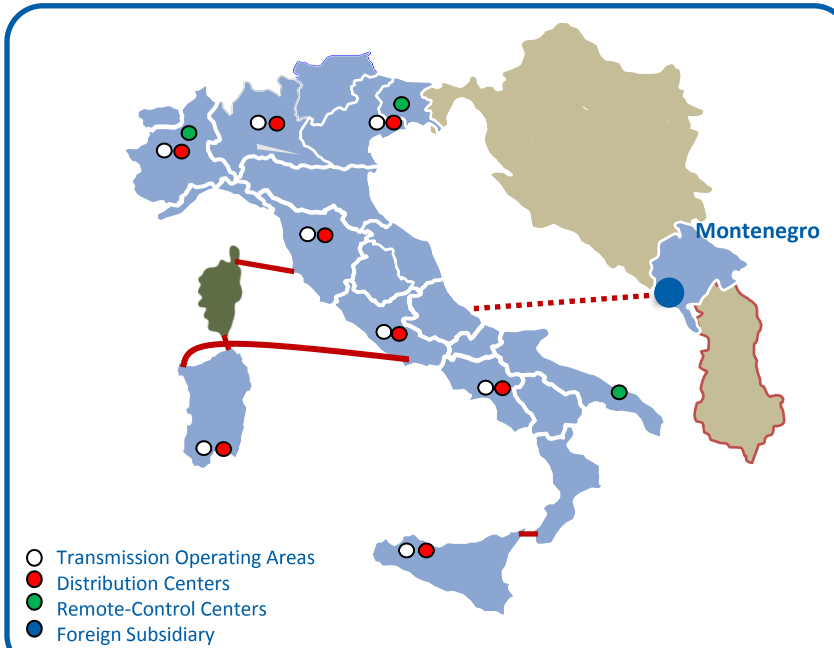
1 Foreign Subsidiary

Electricity Market (2012)*

325 TWh of energy demand

54,113 MW highest peak of demand

... and premises



** provisional figures as of April 2013*

The Italian Context – The Issues

Causes

- Economic crisis and subsequent loss of many big consumers (i.e. national demand decreased 9% from 330 TWh to 300 TWh)
- Aggressive policy of incentives promoting RES + imminence of grid parity
- Short time to fortify and develop the grid to support new scenarios

Effects

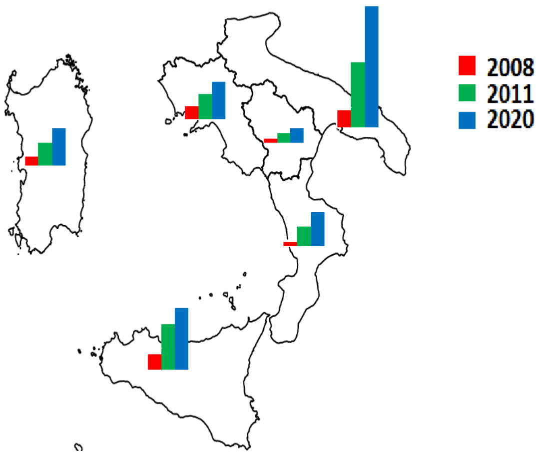
- Fast and massive growth of RES:
  - → *Rise in congestion-related curtailments (i.e. 2010 ~500 GWh lost)*
  - → *Rise in demand for non-spinning reserve*
- Traditional power plants running at minimum load:
  - → *Loss of inertia in smaller insular systems (i.e. Sicily and Sardinia)*
  - → *Loss of available frequency reserves*

Mitigating actions

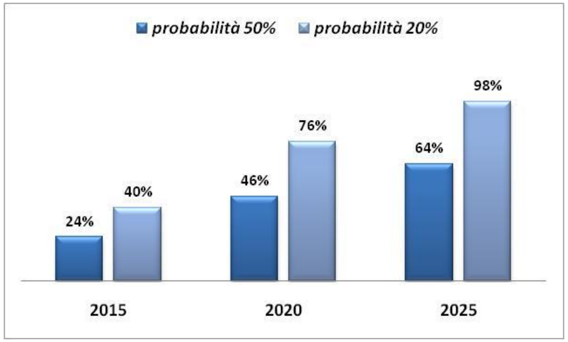
- Optimize integration of RES and increase flexibility of national grid (i.e. smart grid)
- Reduce congestions and ensuing curtailments occurring along critical backbones
- Provide the necessary reserves to the system and improve safety of grid.

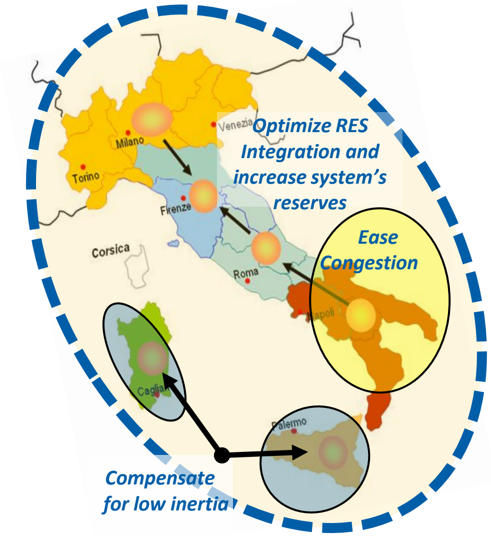
Data analysis

Example: Trend of RES increase in southern and Sicily areas



Example: Percent increase in usage of Tertiary Reserve Up as compared to 2010, with relative probability of purchased hours as caused by the renewable trend





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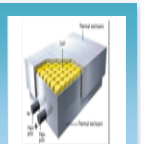
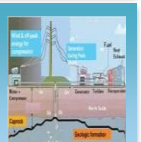
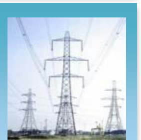
The Italian Context – Solutions Tool Box

	Solutions	Investment required M€/ MW	Deployment time Years	Benefits	Critical points
Demand measure	Virtual Power Plant	Highly variable: depends on number of players and complexity of aggregation	N/A	N/A	▪ High investment ▪ The Business model must be defined ▪ Several stakeholders involved
	Distributed Demand Virtual Aggregator				▪ Market yet to be developed
Storage options	Batteries 	1-3.3	<1	▪ Very fast deployment time	▪ Emerging market ▪ High costs/additional incen needed to break even
	Pumped hydro 	2.0-2.5	5-10	▪ Mature technology	▪ Very long deployment time ▪ Capital expenses site-dependent ▪ Few available sites
	CAES (traditional underground) 	0.5-1.0	5-10	▪ Investment limited compared to other technologies	▪ Difficulties in finding adequate sites ▪ Long & complicated approval process ▪ Limited Applications (site-dependant) ▪ Low round-trip efficiencies
Supply	Infrastructure Development 	0.2-0,315	>10	▪ Cheaper investment Terna core business	▪ Very long deployment time ▪ Does not address all issues

Best Short Term Bet!

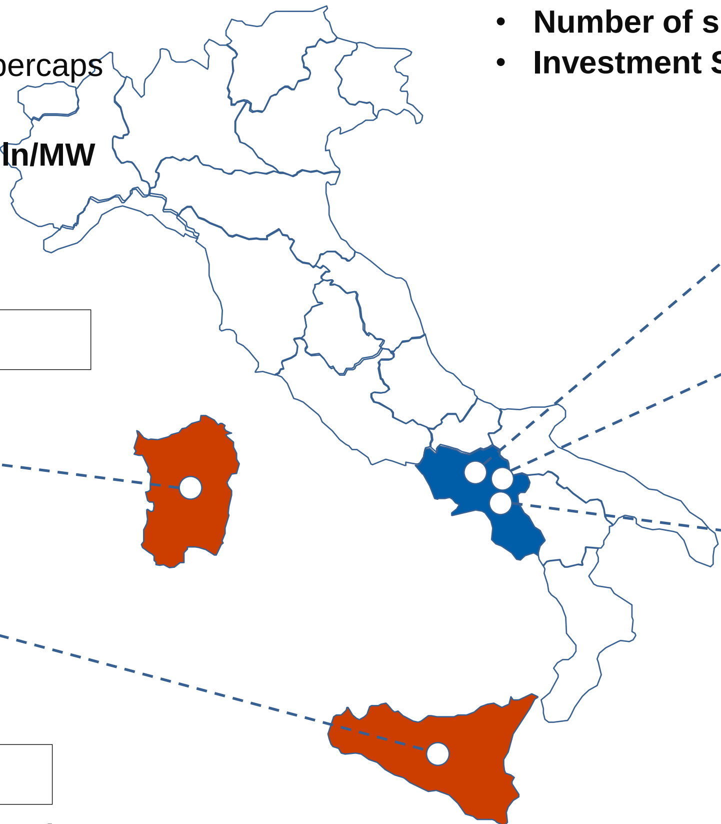
Terna's Storage Projects

Power Intensive

- **Mission:** increase safety of grid
- **Total Power: 40 MW**
- **Solutions:** Li-Ion, Zebra, Flow, Supercaps
- **Number of sites: 2**
- **Investment Size: 93 €mln; 2,3 €mln/MW**

Energy Intensive

- **Mission :** reduce grid congestions
- **Total Power: 35 MW**
- **Solution:** NaS *Sodium Sulfur*
- **Number of sites: 3**
- **Investment Size: 160 €mln; 4,6 €mln/MW**



PHASE I: 16 MW Storage Lab

- **Codrongianos**
- **Total Power: ≈ 8 MW**
- **Status: in commissioning**

- **Ciminna**
- **Total Power: ≈ 8 MW**
- **Status: in commissioning**

PHASE II: 24 MW

Casuzze and Codrongianos: to be initiated

Site 1: Ginestra
- **Total Capacity: ≈ 12 MW**
- **Status: commissioning**

Site 2 Flumeri
- **Total Capacity: ≈ 12 MW**
- **Status: commissioning**

Site 3 Scampitella
- **Total Capacity: ≈ 12 MW (*)**
- **Status: in construction**

(*) more like10,8 MW

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The Concept Behind Terna's Virtual Storage Plant

ORIGINATION

Possible applications for storage

- •Power Quality
- •Black Start
- •Demand charge management
- •Others

TECHNICAL ANALYSIS

Technology characteristics

- •Activation time
- •Storage hours
- •Efficiency
- • # Cycles
- •Others…

\+

Technology constraints

- • Thermal constraints
- • Self-discharge
- •Charging time
- •Aging
- •Others…

ECONOMICAL ANALYSIS

Benefits' Evaluation

- •With/out incentives
- •Market based
- •Others…

\+

Costs' Quantification

- •How much does battery age?
- •O&M's costs?
- •Energy's cost?

BEST TECHNOLOGY PER APPLICATION

- **•Frequency regulation:**
  - -Li-Ion
  - - Flywheels
  - - Others
- **•Load following:**
  - -CAES
  - - NaS
  - -Others
- **•Others**

TESTING AND VALIDATION:

- •Small modules (<100kW)
- •Grid Scale(>1MW)

DEFINITION AND DEVELOPMENT OF A VIRTUAL STORAGE PLANT

A Platform capable of integrating the characteristics and limitations of each technology while maximizing their performance and reducing additional costs stemming from not-optimal usage

Summary of “stand alone” business cases for EESS

GENERATION
- *Market arbitrage/load shifting*
- *Imbalance mitigation*
- *Services to generation (example Diesel optimization)*

RETAIL
- *PV and storage (on grid)*
- *Off-grid (Diesel replacement)*
- *Energy intensive demand management*

SYSTEM OPERATION
- **Primary reserve**
  - **TSO**
  - *Ext. operator*
- **Secondary reserve**
  - **TSO**
  - *Ext. operator*
- **Congestion management**
- **Transmission and Distribution deferral**

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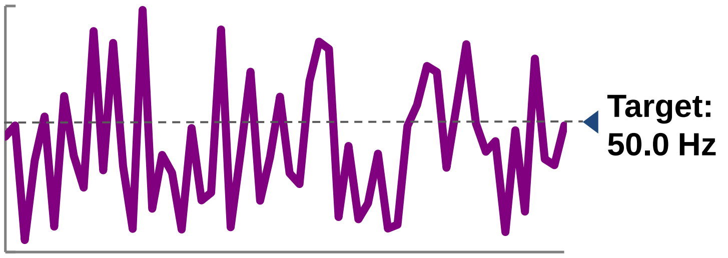
Primary regulation

Primary regulation is compensated in Italy, although reserve capacity is compulsory and not remunerated

Primary reserve ensures that power frequency is always kept at 50 Hz



- **Unforeseen fluctuations** between the feed-in and/or feed-out of electrical energy in the network **cause deviations from** the frequency of **50 Hz**, which **may** rapidly **evolve in power outages**
- Primary reserve **automatically** activates to counterbalance the deviation, contributing to **restore the balance** between power generation and consumption **within seconds** of the fluctuation

Primary reserve is required of energy producers in Italy, while it is remunerated in other countries

Italy[1]

- Energy **producers** are **required to dedicate 1,5%[2]** of total generation **capacity** to primary reserve regulation (excluding renewables and generation units below 10 MVA)
- From April 1st, primary **regulation utilization** is **remunerated** (231/2013/R/EEL)

Foreign countries examples

- In **Germany** primary reserve is bid, and providers are **remunerated only for capacity** (no compensation for imbalance)
- In **UK**, primary reserved is offered through tendering or bilateral contracts; **providers** are paid an **availability fee** (£/h), plus an **utilization payment** for the actual capacity provided (£/MWh)

1 Similar conditions apply to Spain and France
2 10% on Italian islands (Sardinia and Sicily)

Benefit from Primary Regulation

Benefits evaluated based on a model of the Energy Market (MGP 2013)

MGP Benefit

Method: substitute part of primary regulation capacity with battery capacity.

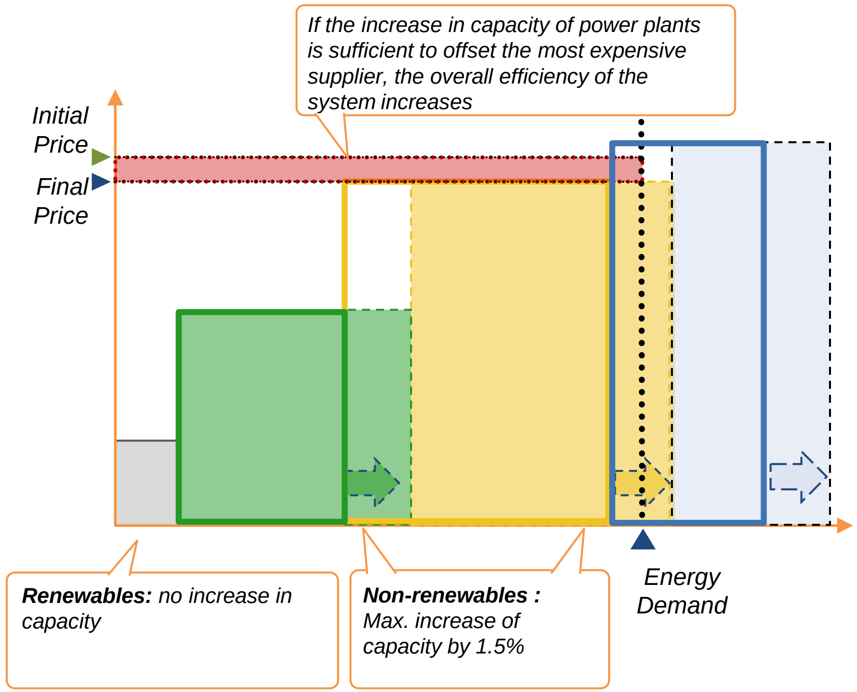
Initial supply from non renewable resources

Final Supply from non-renewable resources

Initial and Final supply from renewable resources

Advantage deriving from release in capacity

Example: MGP shift as a result of reduction of reserve margin



Benefits from Congestion Relief and T&D Deferral – 1

When assessing profitability for Energy Storage Systems different benefits must be taken into account

A

Decrease in the cost of energy

It's possible to accumulate energy during network congestions, thus avoiding curtailments, and to then release that same energy during peak hours, thus decreasing the overall system cost of energy

B

Increase in system safety

The increase in renewable generation has resulted in the following safety issues:

- decrease in primary control reserves;
- decrease in secondary – tertiary control reserves;
- decrease in the system's inertia.

Energy storage, together with Power Conversion System (PCS), can contribute to the solution of these problems

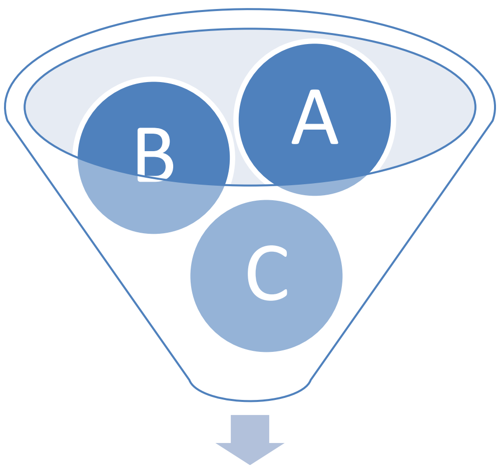
C

Transmission system investment deferral

The ability to supply and absorb electric energy can limit the impact of renewable generation on the grid, thus decreasing the urgency of grid infrastructure development

Benefits from Congestion Relief and T&D Deferral – 2

Energy intensive project's efficiency index



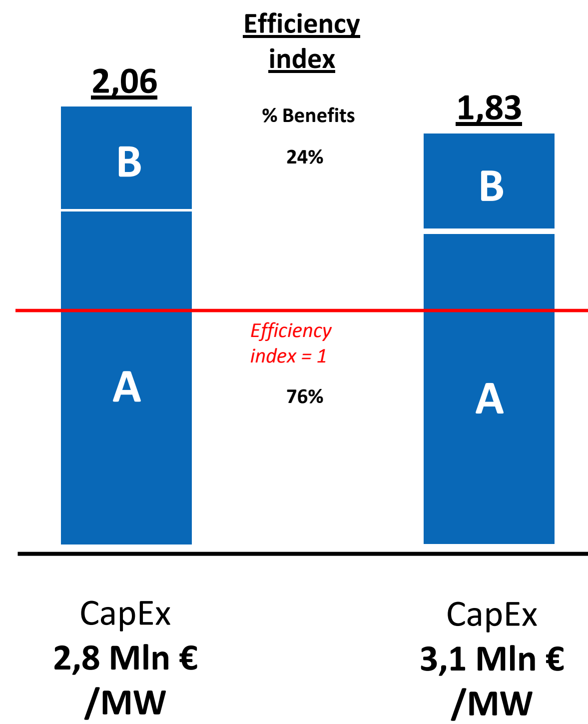
Efficiency index

$$\frac{\text{NPV (A+B)}}{\text{CapEx - C}}$$

Case study – Italian Market

Hypothesis:

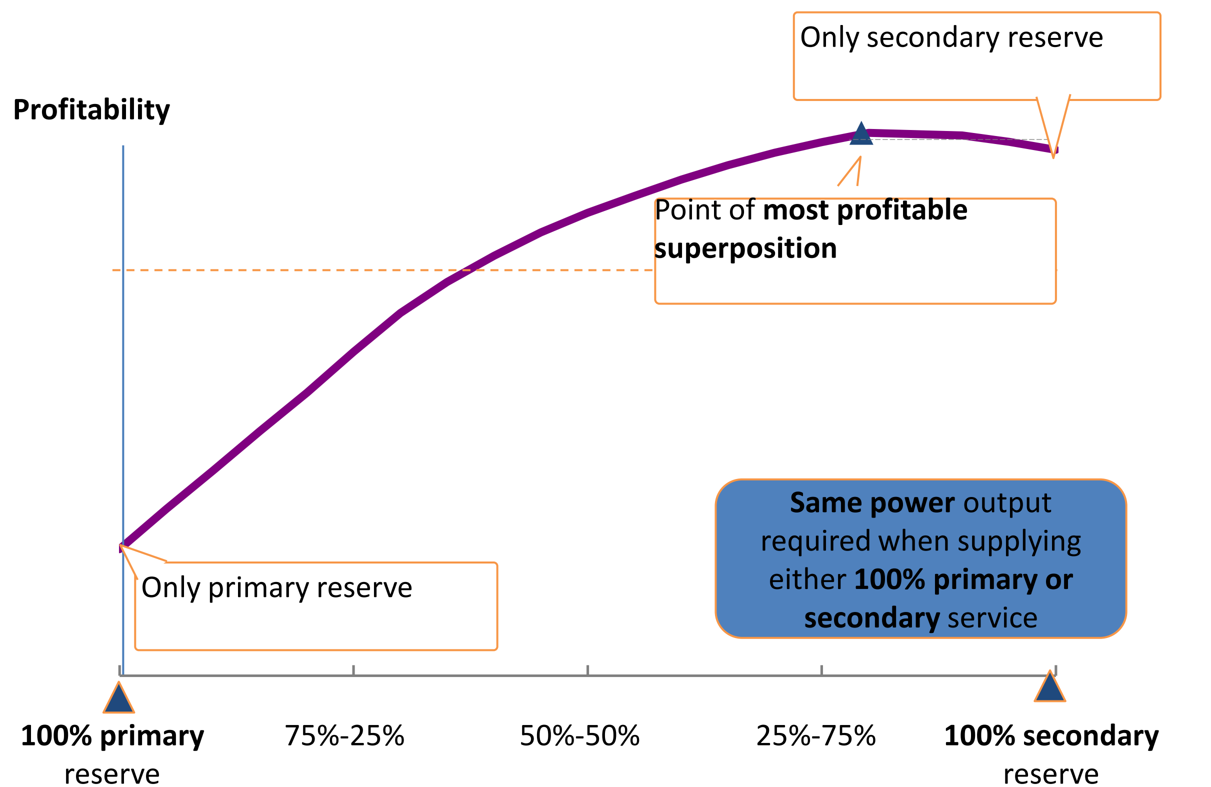
- Hours of avoided congestion: **2500**
- Energy storage efficiency: **75%**
- Hours of primary reserve: **2500**
- Hours of secondary & tertiary reserve: **3744**
- Investment for network's reinforcements deferred "C": **150k€/MW**
- Inflation: **2,2%**



(A) = ΔEnergy€ (B) = System Safety (C) = T&D Deferral

Profitability higher than stand-alone cases can be reached with application integration

Battery profitability for different primary/secondary regulation combination weights



- In "free-float" modality, highest profitability is achieved when **battery power** is dedicated for **70-80% to secondary reserve**. This is mainly because:
  - The value of **secondary** reserve in "free-float" is **~4 times higher** than the value of primary reserve
  - A **limited amount of primary** reserve signal mitigates the secondary reserve request, **reducing** the overall **battery cycles** per year

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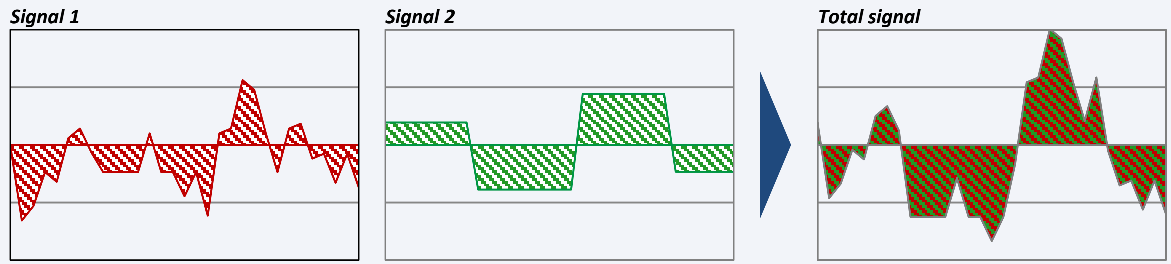
Different batteries and applications can be integrated in multiple ways

Detailed next

Application integration | **Description** | **Example of superposition**

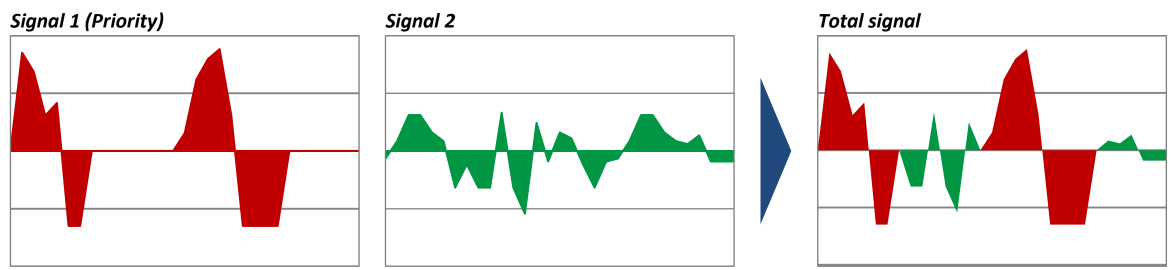
Signal super-position

- Battery follows a **power signal** equal to **combination** of different applications
- Power **bandwidth is allocated** among signals to **maximise profitability**



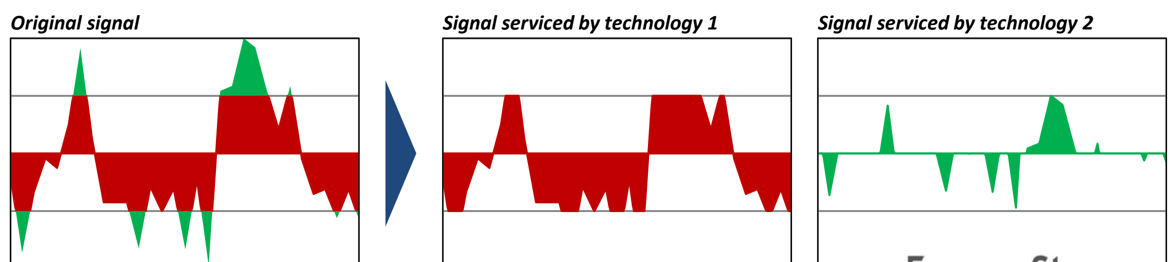
Time allocation

- Battery is **dedicated preferentially** to an application, **but** its utilization is **integrated** with a secondary application when the first one is not requested



Technologies integration

- Original **signal is separated in two components** (one more "energy-intensive" and one more "power intensive"), which are **serviced by different technologies** (each most suitable for the specific signal)



Product development: significant space to improve the value by improving requirements definition

Examples of quotes

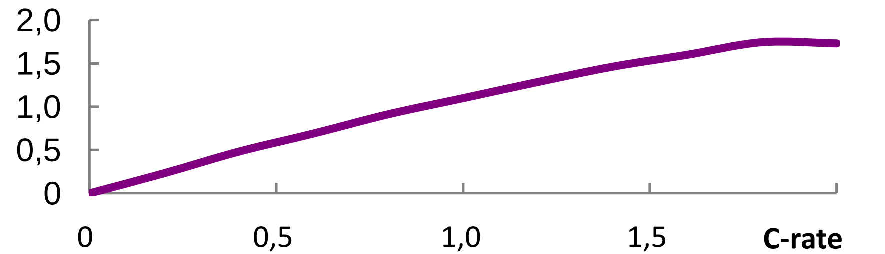
*"We could well design batteries with different **c-rates**, but we don't know what is most needed by our clients and what would deliver the most value "*

*"We are not working explicitly on **life cycles** improvements, as no one asked us to improve this aspect"*

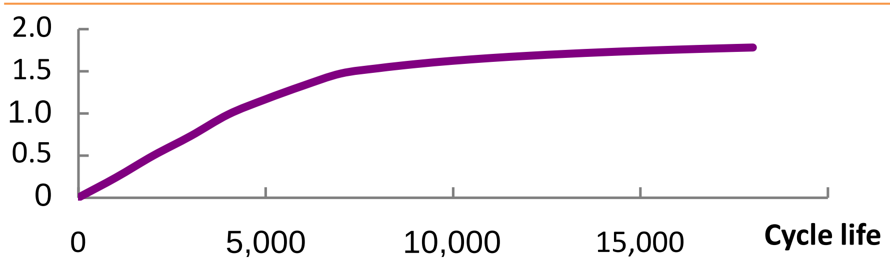
*"If we discuss in detail with the client the **local specific regulation and markets** for the applications of interest we could design much better tailored products"*

Evidences of requirements to be improved

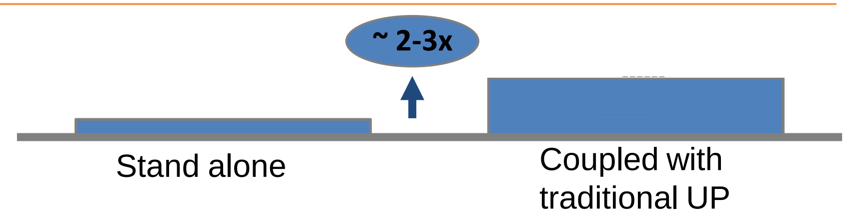
Example of PI at different C-rate - Primary reserve



Example of PI at different Life cycles - Secondary reserve



Example of PI under different regulation assumptions



Beyond Capex: the other 4 parameters that determine value

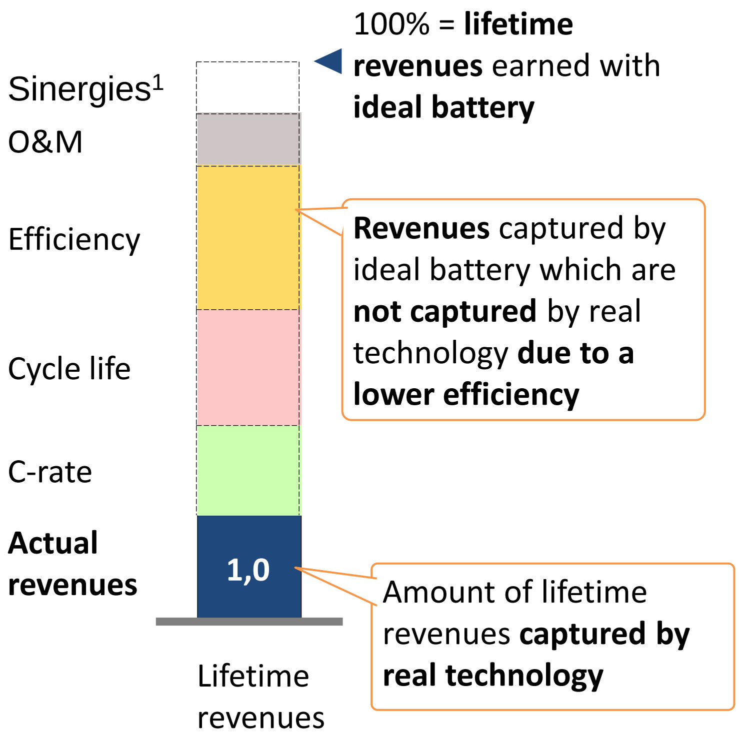
Key specific inputs

- **Battery profitability depends on** both the value of an **application** and the **portion** of such value that can be **captured with current technologies**
- The **objective** of the analysis is to understand, for each technology and selected applications:
  - What is the **maximum** potential **value at stake**
  - What are the **key technological drivers** that would allow the battery **to capture** the entire value

Methodology and assumption

- An **ideal battery** is used to simulate the **maximum value extractable** from each application
- The **ideal battery** hypothesized encompasses for all drivers the **best performances observed** among the different technologies analysed
- The **results** of this battery and its technical characteristics are **compared** with those of real batteries to identify **the key technological drivers that prevent** each real system to **capture the entire value** available
- Part of the potential value not captured **depends on synergies**[1] between multiple drivers, and it is not directly attributable to a single factor

Typical output (detailed in next pages)



1 Effects due to gap vs. ideal battery on more than a single technological driver that, when combined, reduce the value by more than the sum of the stand-alone effect (e.g., while a higher life cycle and a higher C-rate can capture more value, the two together can usually generate even higher revenues than the sum of two effects)

Thank you for your attention